VI.1 COMMENTS ON POISONED SYSTEMS

The use of neutron absorbing materials commonly called "poison" materials within fissile systems increases the critical mass by removing from the system a portion of the neutrons available for the fission process. Such poison materials may be added either homogeneously as soluble poisons in solutions or in the moderator of heterogeneous systems or heterogeneously as Raschig rings, plates, etc. Poisoned interfaces between reflectors and fissile cores will generally increase the critical mass or geometry (but putting a poison material around a bare system will decrease the critical mass or geometry because any material will reflect some neutrons - only space is a perfect absorber). Another neutron absorbing device consists of placing neutron absorbers between separate fissile systems to reduce or eliminate neutron interaction between units. Commonly used poison elements are boron and cadmium although simple hydrogenous materials such as water or concrete can be used as isolating medium to eliminate neutron interaction.

The use of poison materials except as isolators has not been extensively practiced. One reason is that experimental data is relatively scarce and, therefore, correlation between calculation and experiment for practical cases is somewhat difficult. For homogeneous systems with homogeneous poisons, it has been generally recommended that poisons be added at twice the concentration calculated for k_∞ equal to one (the point at which systems of finite size cannot be made critical). However, fairly consistent agreement exists between such widely diverse methods of calculation as diffusion theory, transport theory and Monte Carlo methods (see Figure VI.A.100-1), and it does not seem necessary to always penalize systems of restricted geometry to this extent. (Of course, some of the agreement might well result from all of these calculations using the same cross section sets; a poorly determined cross section set could then result in similar deviations from true values.) We believe a more reasonable approach is to use twice the poison concentration calculated to be necessary to meet general safety criteria.

Some observations on the use of poison materials which may be of value are:

1. It is not necessarily conservative to assume fissile-water systems as the limiting case instead of, say, nitrate systems as is common practice with unpoisoned systems. This can be seen in the graph on page VI.A.100-1, where at high plutonium concentrations more boron is required for the zero molar plutonium nitrate system than for the Pu-$H_2$0 system for identical concentrations. This is a result of the lower H/Pu ratio of the nitrate system. (Had these curves been plotted as a function of the H/Pu ratio instead of concentration the Pu-$H_2$0 system would require more boron at identical H/Pu values.)

2. The use of homogeneous poison must be based on a fail-safe system of poison addition if used as a primary criticality safety control or the required poison concentration must be adjusted to allow for any potential failure of the system.

3. The effectiveness of parallel poison plates at higher concentrations (above 100 g/l) should be considered negligible unless plate spacing is reduced to about one inch or less. Available experimental and calculational data indicate that plate effectiveness is relatively small until a certain critical spacing is reached. Reduction in plate spacing beyond this point increases the critical geometry rapidly (and decreases the fractional free volume of the system).

4. The materials in which solid poisons are incorporated must not dissolve in the environment. For this reasons, materials such as stainless-steel-clad Boral should not be used in acid-containing vessels, since breaching of the cladding would permit dissolution of the poison material, but might be allowed in places such as normally dry sumps.

5. The use of poison interfaces between a core and a reflector to increase the core loading or size is a common practice. However, it should be recognized that some materials such as stainless steel, which act as an interface poison with a reflector of water or other hydrogenous material also may be as good a reflector as water if thick enough. This

means that there can be an optimum thickness for a poison interface. Optimum thickness is about 0.25 inch for boron-stainless steel (1 w/o boron). This arises from the fact that slow neutrons are generally more easily absorbed than fast neutrons and that water (hydrogen) both slows neutrons and scatters them while steel mostly scatters. Fast neutrons going through an interface would thus be slowed down in the water and absorbed while returning through the interface to the core. If a steel interface were thick enough, the neutrons would be scattered back before reaching the water, would not be slowed down appreciably and, hence, would not be absorbed in the steel. Loss of poison material due to corrosion of the interface must also be considered in any design.

6. Isolation of fissile systems is generally considered complete by the use of certain material thicknesses, for example, 10 to 12 inches of water or concrete. However, reduction of isolator thicknesses to half or three-fourths of these values may not cause a significant increase in the k-effective of individual fissile units in an array. Significant savings in the use of isolating materials might be achieved if experimental data can be applied to particular cases or if accurate calculational methods are available.